# Uncompensated spins in antiferromagnetic NiO coupled to a ferromagnet

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## INTRODUCTION

The current interest in magnetic multilayers is driven by the interesting physics as well as by their application in the magnetic-storage industry [1]. One example is the so called exchange bias effect, because of its use in modern magnetic data storage devices. Exchange bias is referred to the effect of aligning (pinning) the magnetization direction of a ferromagnet by coupling it to an antiferromagnet. The existence of the exchange bias phenomenon has been known for more than 45 years [2], but the origin of this effect remains an active research area as has been recently reviewed [3,4]. An important parameter in modeling the exchange bias effect are possible uncompensated spins in the antiferromagnet. The origin of these uncompensated spins is unclear and the relative orientation to the ferromagnetic moment is hotly debated. Here we present results obtained with X-ray magnetic circular dichroism (XMCD) which reveals a parallel coupling of uncompensated spins in polycrystalline NiO and the ferromagnetic moment in an adjacent Co layer. The experiment was performed at the elliptically polarizing undulator beamline 4.0.2 of the Advanced Light Source. Due to its full control over the polarization of the X-rays this beamline is ideally suited for this kind of experiments.

## EXPERIMENT

The sample studied was a 3 nm thin Co film on top of 50 nm NiO film grown on Si. The Co film was capped with a 1.5 nm Ru layer to prevent its oxidation. The easy axis of the Co layer was in the plane of the sample and after the “setting” procedure (annealing the sample above the Néel temperature and cooling it in a magnetic field) an exchange bias field of 175 Oe was obtained.

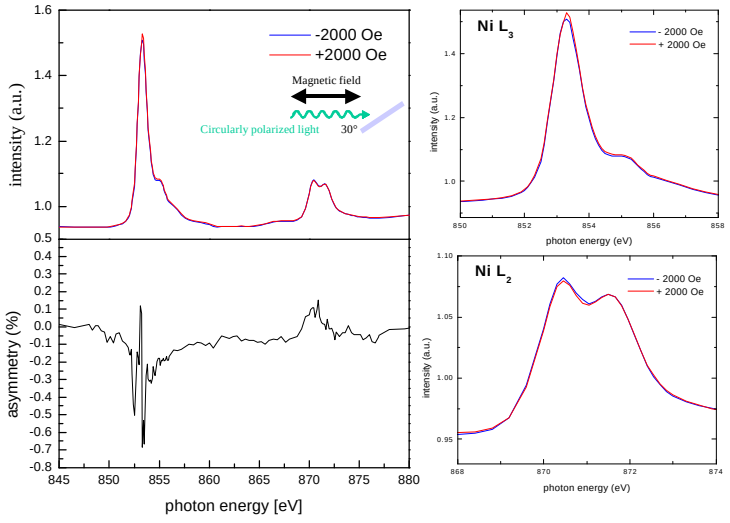


Figure 1: Absorption spectrum and XMCD asymmetry of the Ni L3,2 edge. The polarization was fixed and the magnetic field was switched at each energy. The experimental geometry is shown.

The XMCD spectra were measured in the absorption mode by measuring the sample current (typical sample current was 1 nA). The sample was mounted in the gap of an electromagnet, which can switch a magnetic field up to 3000 Oe with 1 Hz. The magnetic field was along the polarization vector of the circularly polarized light and the data were acquired in an applied field, which was switch at each energy point between ±1000 Oe while the polarization of the X-rays was fixed.

Figure 1 shows the spectrum and the XMCD asymmetry of NiO measured

at the Ni $L_{3,2}$ edge with right circularly polarized light, the degree of polarization being 64 %. The sample was measured in grazing incidence (30%) such that the in-plane moment was measured. The asymmetry shows a dichroism at the Ni $L_3$ with an opposite sign at the Ni $L_2$ edge, which can already be seen in the raw data shown on the right of Figure 1. Repeating this measurement with left circularly polarized light yields the reversed asymmetry as shown in Figure 2 a). Note that the plot extends down to 800 eV such that the flank of the Co $L_2$ peak is included. The experiment was repeated in a normal incidence geometry, which is sensitive to the out-of-plane moment. Since the easy axis of the Co layer is in the plane, the obtained magnetic dichroism vanishes as

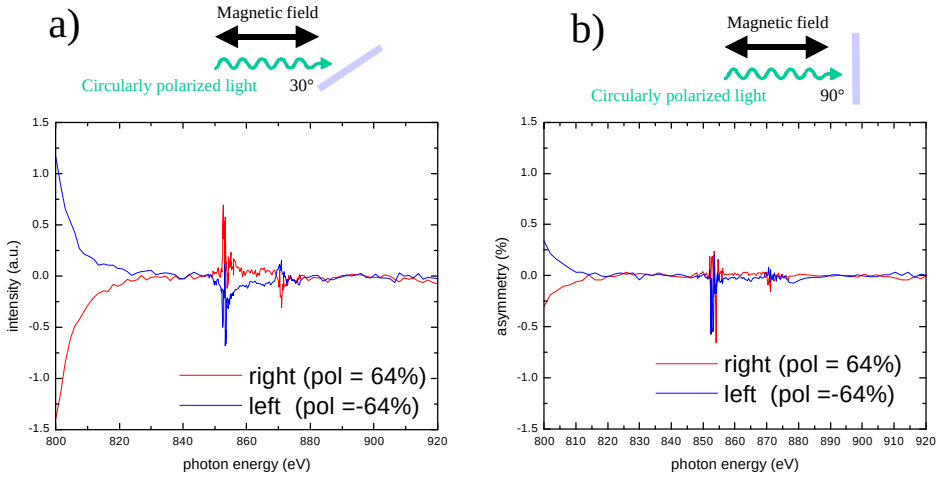


Figure 2. The XMCD asymmetry measured in grazing a) and in normal b) incidence. The plot extends down to 800 eV to include the flank of the Co $L_2$ edge.

expected (see Figure 2b).

XMCD measurements at the Co $L_{3,2}$ edge (not shown) reveals a parallel coupling between the uncompensated spins in NiO and the ferromagnetic moment of the Co layer. The origin of the uncompensated spins in NiO is not clear, but may be due to oxidation/reduction at the Co/NiO interface, as the Co was found to be slightly oxidized. XMLD experiments to determine a preferential antiferromagnetic axis in NiO and in the slightly oxidized Co showed no preferred orientation, neither in-plane nor out-of-plane.

The next step will be to measure the hysteresis loop of the uncompensated NiO spins and to correlate it with the one of Co.

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